A Geographic Information System for the Characterization and Modeling of Multiscale Remote-Sensing Data Using Fractals and Spatial Techniques

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Objectives

- To develop a user-friendly geographic information system software package called ICAMS for the characterization and analysis of multiscale remote-sensing data for global change and environmental modeling studies.

- ICAMS stands for Image Characterization And Modeling System.

- Main techniques include: fractals, boundary delineation, spatial statistics, aggregation and scale analysis.

- Year One focuses on the design and implementation of ICAMS.

- Year Two evaluates the reliability and effectiveness of the various algorithms in characterizing remote-sensing images at different scales, utilizing ICAMS developed in Year One.

Image Characterization And Modeling System

- ICAMS
  - Image Input
    - Format Transformation
    - Geo-referencing
    - Co-registration
    - Noise Removal/ Filtering
  - Image Characterization
    - Histograms
    - Fractal Analysis
    - Spatial Autocorrelation
    - Textural Measures
  - Specialized Functions
    - Temperature
    - Land/Water Interface
    - Vegetated/Non-vegetated
    - Aggregation Routines (Multiscale Analysis)
  - Image
    - 3-d maps
    - Statistics Ouput
    - Digital Image Output

Technical Approach

Task 1: Software Development

- Provide specialized functions that are not available in any existing GIS/RS software, such as fractal analysis, variogram analysis, and multiscale analysis.

- Build upon existing commercial GIS software, including Arc/Info (Live Link with Erdas Imagine) , Intergraph.

  Rationale: Minimize duplication
  Large user community

- Software evaluation: use a standard data set to test all modules.

Technical Approach

Task 2: Evaluation of the fractal algorithms and other spatial techniques

- Benchmark study on how the fractal dimensions differ using different fractal measuring algorithms, using:

  A standard data set;

  theoretical surfaces (white-noise);

  simulated autocorrelated surfaces.

- How the fractal dimensions are affected by differing pixel resolutions, spectrum ranges, and sensors.

- How the fractal results differ from those of the spatial techniques.

Technical Approach

Task 3: Analysis of Multiscale data

- Select study sites that have:
  - multiscale remote-sensing data (Landsat-TM, MSS, and AVHRR);
  - different landscape types;
  - sufficient ancillary data.

- Apply the functions in ICAMS, compute indices, and evaluate the changes in indices due to scale changes.

Current Status

Task 1: Software Development

- Major functions completed on Arc/Info SUN platform.
- Major functions completed on Intergraph MGE platform.

In progress

- Transferring to Intergraph Windows-NT
- Transferring to PC Arc/View
- Transferring to PC standalone
- Refining existing functions
- Adding other options to some of the modules

Current Status

Tasks 2&3: Evaluation of Fractal Algorithms and Multiscale Analysis

A pilot study

- Use a Landsat-TM image of Lake Charles, LA.
- Create a subset with 201x201 pixels.
- Compare the fractal dimensions using the isarithm and the variogram methods.
- Resample the original image using a 2x2 window.
- Compare the descriptive statistics and the fractal dimension values.
- See Tables 1, 2, and 3.

Results / Lessons Learned

- Discrepancies in results from the two fractal methods exist.
- Each method has its own set of parameter input values that will affect the final D.
- Variogram method generally overestimates D; but the range of points defining D reflect the spatial characteristic of the image well.
- Isarithm method generally is more stable.
- Resampling method may be the key in affecting the performance of scale analysis.
- The resampled image generally has lower standard deviations but higher fractal dimensions.

Next Steps

- Complete the Window-NT version.
- Complete the PC standalone version.
- Refine ICAMS.
- The pilot study leads to concrete suggestions to improvement of existing fractal method.
- Perform evaluation using theoretical surfaces.
- Identify three study sites for detailed evaluation:

  Nevada (dry natural landscape);

  Huntsville (urban, vegetated);

  Coastal Louisiana (coastal).

Table 1
Summary statistics of the original (201x201) and the resampled (101x101) images

	Original image				Resampled image			
Band	Min	Max	Mean	S.D.	Min	Max	Mean	S.D.
1	40	255	70.37	12.95	54.50	170.75	70.39	11.51
2	13	126	27.40	7.57	17.50	83.50	27.41	6.76
3	8	158	30.95	11.20	15.25	108.50	30.97	10.10
4	4	138	45.98	11.82	6.25	89.00	45.95	10.61
5	0	232	52.07	17.28	2.25	147.50	52.07	16.06
6	116	146	132.37	3.61	116.25	145.50	132.37	3.57
7	0	148	22.37	9.96	0.25	82.00	22.38	9.25

Table 2
Fractal dimension and r^2 values (in parentheses) computed for the original and the resampled image using the isarithm method *

Band	Original Image	Resampled Image
1	2.77(0.86)	2.90(0.97)
2	2.84(0.92)	2.92(0.98)
3	2.85(0.92)	2.89(0.99)
4	2.67(0.93)	2.76(0.97)
5	2.68(0.98)	2.72(0.94)
6	2.39(0.93)	2.56(0.96)
7	2.89(0.98)	2.89(0.96)

* Parameter inputs are: isarithmic interval = 10;
number of walks = 6;
direction = both row and column

Table 3

Fractal dimension and r^2 values (in parentheses) computed for the original and the resampled image using the variogram method *

Band	Original Image	Resampled Image
1		
2		
3		
4	2.84(0.63)[49]	2.86(0.66)[46]
5		
6		
7		

* Breakpoints were selected to maximize the distance range and that the r^2 exceeds 0.60. The numbers in brackets indicate the last distance point included in the regression. For example, the range of points included in Band 1 of the original image is from Point 1 to Point 27. There are totally 50 distance groups (points).

Some Questions that we will address with ICAMS

- Do different environmental processes (e.g., coastlines, vegetation boundaries) have their own fractal dimensions?
- How is the fractal dimension of an image affected by the resolution of the sensor?
- How does the fractal dimension compare with the more conventional spatial techniques in the effectiveness in characterizing image and multiscale image data?
- Can we identify areas with different properties (e.g., vegetation v.s. bare ground) by measuring the corresponding fractal dimensions?
- What is the significance of *changes* in fractal dimension, either in time or space?
- How can we use fractal analysis to identify specific patterns of land cover, terrain, and so forth?
- How will the land/water or vegetated/non-vegetated boundaries, the NDVI, and the temperature change with scale?